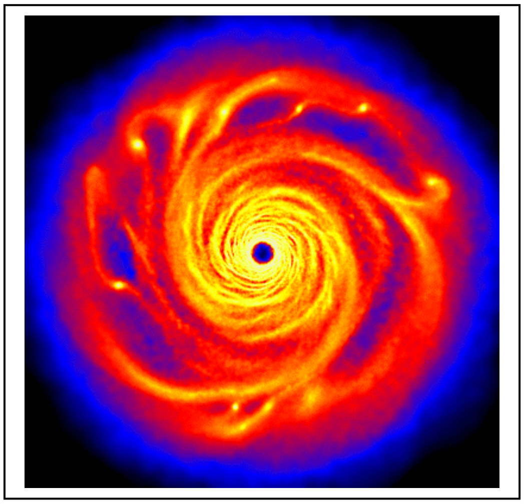
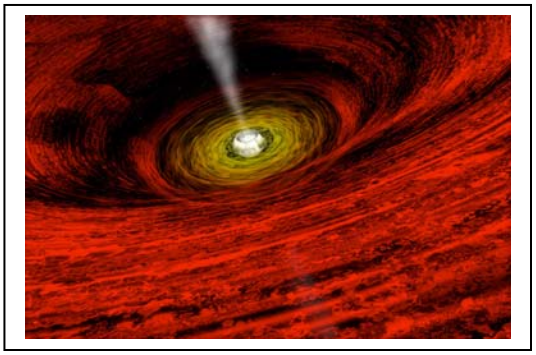
Black Holes...Hot Stuff!....VIII





Top -Computer model of an accretion disk model. (Courtesy: Ken Rice - UCR)

Bottom - Artist's painting of an accretion disk (Courtesy: April Hobart, NASA/Chandra/CXC)

The farther a particle falls towards a black hole, the faster it travels, and the more kinetic energy it has. Kinetic energy is mathematically defined as K.E. = 1/2 m V^2 where m is the mass of a the particle and v is its speed.

Suppose all this energy was converted into heat energy by friction as the particle falls, and that this added energy causes nearby gases to heat up. How hot will they get? The equivalent amount of thermal energy carried by a single particle is

$$T.E = 3/2\ kT$$

where k = Boltzman's Constant 1.38 x 10^{-16} erg/deg. If we set K.E = T.E we get

$$T = 3\ mV^2 / k$$

If all the particles in a gas carried this same kinetic energy, then we would say the gas has a temperature of T degrees Kelvin. We also know that the potential energy of the particle is given by

$$P.E = 2\ G\ M\ m / R$$

So if we set P.E = T.E we also get

$$T = 4/3\ G\ M\ m / k\ R$$

Problem 1 - The formula T = 4/3 G M m/kR gives the approximate temperature of hydrogen gas (m = 1.6 x 10^{-24} grams) in an accretion disk around a black hole. What is the temperature for a solar-mass black hole disk near the orbit of Earth? (R = 1.47 x 10^{13} cm, M = 1.9 x 10^{33} grams, for G = 6.67 x 10^{-8})?

Problem 2 - How hot would the disk be at the distance of Neptune (R = 4.4 x 10^{14} cm)?

Problem 3 - X-rays are the most common forms of energy produced at temperatures above 100,000 K. Visible light is produced at temperatures above 2,000 K. What would you expect to see if you studied the accretion disk around a black hole?

Answer Key:

Problem 1 - The formula T = 4/3 G M m/kR gives the approximate temperature of hydrogen gas (m = 1.6×10^{-24} grams) in an accretion disk around a black hole. What is the temperature for a solar-mass black hole disk near the orbit of Earth? (R = 1.47×10^{13} cm, M = 1.9×10^{33} grams, for G = 6.67×10^{-8})?

Answer: $4/3 \times 6.67 \times 10^{-8} \times 1.9 \times 10^{33} \times 1.6 \times 10^{-24} / (1.38 \times 10^{-16} \times 1.47 \times 10^{13})$
= 133,000 K.

Problem 2 - How hot would the disk be at the distance of Neptune (R = 4.4 x 1014 cm)?

Answer: $4/3 \times 6.67 \times 10^{-8} \times 1.9 \times 10^{33} \times 1.6 \times 10^{-24} / (1.38 \times 10^{-16} \times 4.4 \times 10^{14})$ = 4,400 K.

Problem 3 - X-rays are the most common forms of energy produced at temperatures above 100,000 K. Visible light is produced at temperatures above 2,000 K. What would you expect to see if you studied the accretion disk around a black hole?

Answer: The inner disk region would be an intense source of x-rays and visible light, because the gas is mostly at temperatures above 100,000 K .In the outer disk, the gas is much cooler and emits mostly visible light.